

Two-fluid simulations of solar partially ionized atmosphere

May 8, 2016

Ever fascinating sun

Ra



Copyright 2013. Barcelona Supercomputing Center - BSC



Studying the sun(observations)

- The first written record of sunspots was made by Chinese astronomers around 800 B.C
- 1982 years before the first drawing

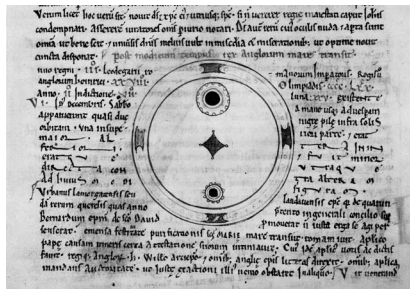


Figure 1: The earliest known drawing of sunspots appears in The Chronicle of John of Worcester and predates the invention of the telescope by almost 500 years. The sunspot was recorded in medieval England in 1182, according to astronomer F. Richard Stephenson at the University of Durham.

Studying the sun(observations)

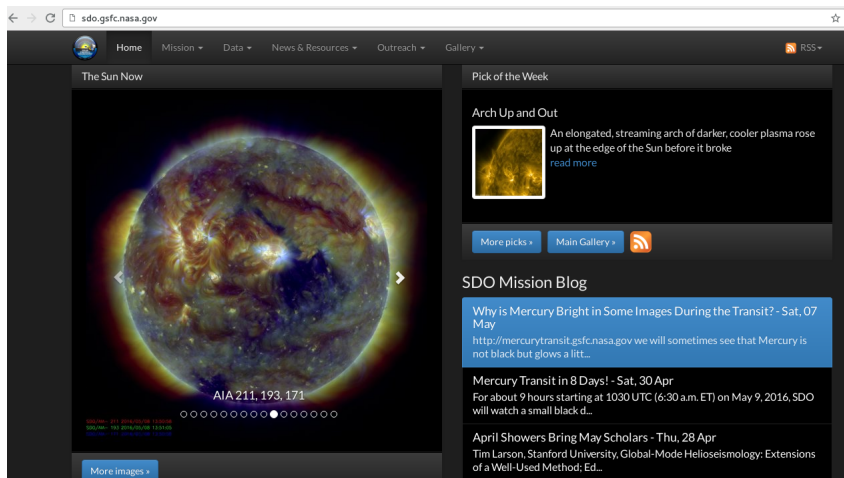


Figure 2: SDO space telescope live images of the sun in several wavelengths

Mysteries of the sun

- solar cycle

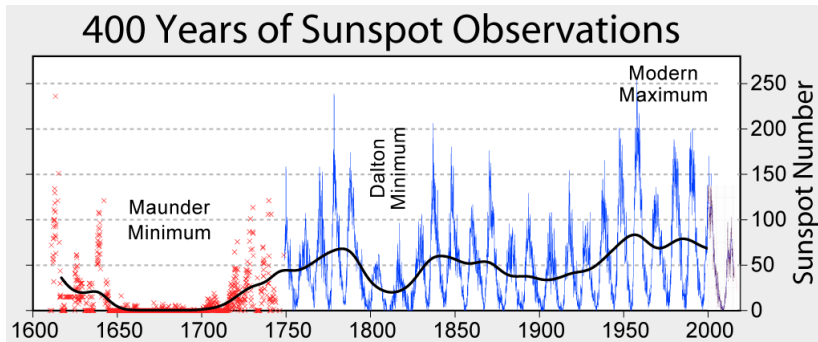


Figure 3: solar magnetic activity cycle is the nearly periodic 11-year change in the Sun's activity

Mysteries of the sun

- the mechanism of the generation of a magnetic field thousands times stronger than on earth concentrated in spots as large as earth (the sunspots)
- coronal heating: above the photosphere at around 6000 K the temperature rises abruptly at over 1 million degrees

Studying the sun(theoretical models)

Sun as a plasma(a gas containing neutral and charged particles, but globally electrically neutral with collective behaviour)

- main sequence star burning hydrogen into helium into its core
- the sun atmosphere is composed mainly of H and He (the proportion of number of atoms H:He is 10:1 and the metallicity estimated $Z = 0.0122$)
- neutral atoms in the photosphere start to become ionized in the chromosphere where temperature starts to rise and are fully ionized in the corona Plasma models
- Fluid equations
- Maxwell equations describing the electromagnetic field

Plasma models

- system of first order non linear partial differential equations which must be integrated in time
- fluid mechanics equations derived (in statistical physics) from Boltzmann equation for variables like density, pressure and velocity
- induction equation derived from Maxwell equations and Ohm law for the evolution of the magnetic field
- Approximations:
 - MHD: all the particles are considered as a whole. Assumption: strongly collisional plasma. A system of 8 unknown variables $(p, \rho, v_x, v_y, v_z, B_x, B_y, B_z)$
 - 2-fluid: Neutral particles do not feel electromagnetic forces and may move differently from charged particles so collision rates between charged particles and neutral particles may not be the same like inside one specie. We consider the fluid variables (p, ρ, v_x, v_y, v_z) different for charged and neutral particles. A system of 13 unknown variables.